Report on

MINI-CONFERENCE ON SLUDGE DISPOSAL ALTERNATIVES IN THE OCEAN OFF SOUTHERN CALIFORNIA

8 September 1976

Edited by

MORTON S. ISAACSON

NORMAN H. BROOKS

EQL MEMORANDUM NO. 19

December 1976

Environmental Quality Laboratory
CALIFORNIA INSTITUTE OF TECHNOLOGY
Pasadena, California 91125

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ACKNOWLEDGEMENT

Both the Conference and this report were made possible by a Ford Foundation grant (No. 740-0469) to the Environmental Quality Laboratory for general support.

Special thanks go to Dr. William Faisst, who did most of the work in organizing the conference, assisted by Ms. Nora Fort of EQL's secretarial staff. We would also like to thank James Hunt, James Kuwabara and Dr. Robert Koh for their aid in the preparation of Chapter 4.

N. H. Brooks
J. J. Morgan
Conference chairmen

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CHAPTER 1
INTRODUCTION

The purpose of the conference was to review the status of our capability to predict the environmental effects of the disposal of digested sewage sludge in the ocean off the coast of Southern California. At present, the ocean disposal of sewage sludge is prohibited by State and Federal regulations. Ocean disposal of sludge, however, is a complex of many alternative combinations of what, where and how; and the environmental consequences of all such combinations have not yet been determined. There is, in fact, some evidence that at least one environmentally sound mode of sludge disposal in the ocean off the Southern California coast may exist. This is the trapping of sludge in the sediments of deep, nearshore ocean basins, such as the Santa Monica Basin. Details of this method are given in Section 3.3, p. 12.

It is the philosophy of the Environmental Quality Laboratory to study and evaluate policy alternatives but not to be an advocate of one alternative or another. Some of the policies studied may be contrary to existing laws or regulations, but it is believed that there is a better chance for improvement in the laws or regulations if alternatives currently outside them are also studied. The conference was sponsored by the Environmental Quality Laboratory in the belief that sufficient information is now available to begin making reasonable estimates of the environmental consequences of existing or alternative ocean disposal methods in order to compare them to land-based disposal methods.

The purpose of this report is <u>not</u> to publish the actual proceedings of the conference, but rather to act as a communications aid. It is intended to publicize the issues that were raised at the conference, to give the names and addresses of people who are involved in these issues, and to present abstracts and literature citations.

The schedule of the conference is presented in the next section. It is followed by a section containing abstracts of current research by conference attendees along with reference lists supplied by them. The fourth section is a summary of the afternoon discussion sessions. The final section is a list of conference attendees with their mailing addresses.

CHAPTER 2

PROGRAM FOR THE MINI-CONFERENCE ON SLUDGE DISPOSAL ALTERNATIVES IN THE OCEAN OFF SOUTHERN CALIFORNIA

Sponsored by

ENVIRONMENTAL QUALITY LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
Pasadena, California

8 September 1976 - 9:00 a.m. to 4:15 p.m.

Caltech Campus - The Salvatori Seminar Room, 365 South Mudd

8:30 a.m. - Sign in and coffee

Morning Session - Chairman, Jack E. McKee, *Professor of Environmental Engineering, Caltech**

9:00 a.m. - Welcome and Introductory Comments - Norman H. Brooks, *Director, Environmental Quality Laboratory; James Irvine Professor of Environmental Engineering Science, Caltech*

9:15 a.m. - Recent Measurements of Sludge Sediments off the Seven-Mile Outfall, Santa Monica Bay, and around Palos Verdes - Willard Bascom, *Director*, and David Young, *Senior Environmental Specialist, Southern California Coastal Water Research Project*

9:50 a.m. - Advanced Treatment Disposal and Marine Environmental Effects in the Los Angeles County Sanitation Districts System - Irwin Haydock, *Environmental Scientist*, and James Stahl, *Supervising Civil Engineer, County Sanitation Districts of Los Angeles County*

10:30 a.m. - Coffee break

10:45 a.m. - The Deep Water Disposal Alternative: Modeling for Sludge Disposal in Santa Monica and San Pedro Basins - William K. Faisst, *Consultant to EQL, Caltech*

11:10 a.m. - Sedimentation Modeling for Sludge in Seawater - Robert C. Y. Koh, *Research Associate, Environmental Engineering Science, Caltech*

11:40 a.m. - Open discussion

11:50 a.m. - Adjourn for lunch

-Each talk will be followed by a short question/answer period.

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*Could not attend on account of illness; substitute was Norman Brooks.

Afternoon Session

1:15 p.m. - Ocean Disposal Alternatives - Moderator: Norman H. Brooks

2:05 p.m. - Data Availability and Needs - Moderator: Willard Bascom

3:00 p.m. - Coffee

3:10 p.m. - Environmental and Ecological Consequences of Ocean Sludge Disposal - Moderator: James J. Morgan, *Executive Officer, Environmental Engineering Science, Caltech*

4:15 p.m. - Adjourn

CHAPTER 3

ABSTRACTS OF CURRENT RESEARCH BY CONFERENCE ATTENDEES

This section contains abstracts of current research submitted by some of the speakers and several attendees at the conference. A list of relevant references follows each abstract, if such a list was provided by the author. (The ordering of the abstracts is alphabetical by name of the author.)

3.1 SLUDGE IN SANTA MONICA BAY

Willard Bascom

Director, Southern California Coastal
Water Research Project
El Segundo, California

The Southern California Coastal Water Research Project (SCCWRP) has been studying the effects of sludge discharged into Santa Monica Bay for five years. The amount of solids released and the circumstances of discharge are described in an accompanying paper entitled, "Waste Solids Entering the Ocean in the Los Angeles Area" (see 3.2, p.9).

In the past we have taken scattered samples throughout Santa Monica Bay; this year we sampled 43 stations on a 400 meter grid just seaward of the end of the pipe to better define the main sludge deposit. By smelling the samples brought up by the grab one can make a reasonably good initial estimate of the sludge concentration and distribution. Sub-samples from these grabs are later analyzed in the laboratory for volatile solids and metals. These give numerical values and permit the affected area to be contoured. PCB values give an even more precise indication of the outward movement of waste solids.

The background level of volatile solids in Santa Monica Bay is 3%; this figure rises abruptly to 10% to define the sludge area (see Figure 3.1.1). Within that area metals values are 4 to 111 times background.

There are 24 species and 16,800 individuals per square meter of benthic animals larger than 1 mm in the sludge-affected area versus 50 species and 1,200 individuals in the control area.

Rockfish are numerous in the area; they appear to be attracted both by the pipe (and its attached life) and by the food in the discharge. In a 5.5 hour hook-and-line fishing test, 47 fish representing 6 species and weighing 22.7 kg were caught in the affected area; this is well above the catch in the unaffected areas.

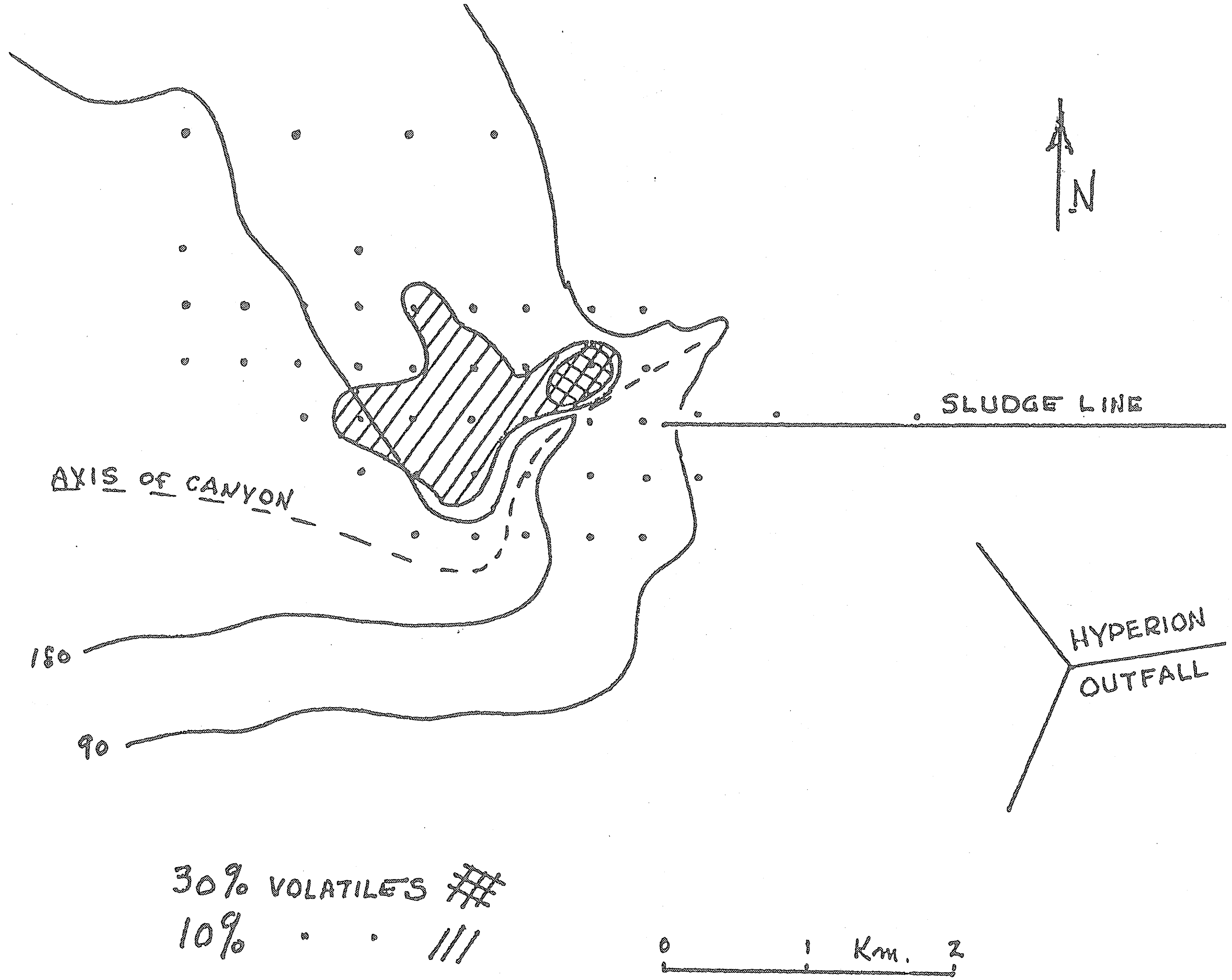

Figure 3.1.1 Volatile content of surficial bottom sediments in the vicinity of Hyperion Sludge Outfall in Santa Monica Bay (June, 1976).

Dover sole (a bottom-feeding flatfish) is relatively abundant in the vicinity of the sludge discharge. Of the specimens taken by trawl in this area between 1971 and 1974, 10 percent have a fin erosion disease.

The area of bottom that contains a significant amount of sludge was (in June 1976) about 2 square kilometers, Figure 3.1.1. A re-check on August 20, 1976 failed to find any visually identifiable sludge. In either case only a small part of the material discharged remains in the discharge area. Probably it disperses by some combination of the following mechanisms: (1) drifts off in the subthermocline currents, probably towards deep water, (2) is eaten by sea animals or chemically broken down into finer particles, (3) accumulates in a temporary pile at the head of the canyon which periodically slides down canyon in a turbidity current.

We do not see any substantial change in the situation in the last 5 years. Sludge is not coming ashore or building up on the bottom. The situation seems to be harmless and stable.

3.2 WASTE SOLIDS ENTERING THE OCEAN IN THE LOS ANGELES AREA

Willard Bascom

Director, Southern California Coastal
Water Research Project

El Segundo, California

Various materials on the sea bottom near outfall areas have been called sludge. In order to make the situation more understandable we have assembled some data on the amounts of solids being discharged and on the characteristics of the discharge sites (see Table 3.2.1).

Los Angeles City separates sludge from wastewater by both primary and secondary treatment at the Hyperion Plant. These sludges (1.3 mgd or 4,900 m^3 per day of screened digested primary sludge and 1.0 mgd or 3,800 m^3 per day of activated secondary sludge) are mixed with 2.5 mgd (9,500 m^3/day) of secondary effluent and discharged through a (nearly) seven mile (11.5 km) long 24" (61 cm) diameter pipe (without diffusers) at the head of Santa Monica Canyon. Thus the daily total is 4.8 mgd (18,200 m^3/day). This contains 0.78% solids (7,800 mg/L) equivalent to 190 metric tons (205 short tons) of solids per day.

Water depth at discharge point is 320 ft (100 m) and the slope of the axis of the canyon just below that point is 1:11. Measurements of water motions at 420 m depths in the canyon with a current meter (Sept. 12 to Oct. 4, 1974) showed the net downward current to be 3.5 cm/sec with no long-term upcanyon motions.

Small amounts of PCB discharged with the sludge can be used to trace its motion (laboratory tests show that PCB does not desorb from sludge particles for at least a year). Thus, sediment samples show that PCB levels decrease rapidly away from the outfall point to one tenth of the initial level half way to shore. Metals values decrease in a similar way, generally reaching background within 4 km (direction of highest values).

Table 3.2.1

Metal Concentrations (In ppm dry weight) in Sludge Discharge Area and in Santa Monica Bay

	Dried Seven Mile Effluent 1975	Santa Monica Bay Sediments Estimated Background[1]	Outfall Sediment Peak Level 1976	Average Level in Sludge Area* 1976	Enrichment Ratio for Average Level in Sludge area	Background Seawater Concentration[2] (ppb)
Cadmium	113.6	.22	65	24.4	111	0.05
Lead	100	7.	597	127.6	18	0.2
Nickel	300	15.	231	57.4	4	1.0
Chromium	1,136.0	62.	1,279	275.	4	0.2
	(97% + 3) (3% + 6)					
Mercury	10.4	0.043	6.4	1.9	44	0.03
	∝ 90% in sulfide < 10% organic					
Silver	28.2	0.71	41.8	7.0	10	0.01
Copper	1,631.	13.	1,010.	294.	23	0.2

*Stations with 73% Volatile Solids

[1]SCCWRP Three Year Report 1973

[2]California Water Pollution Control Assoc. Bulletin July 1976

The greatest depths of sludge we have measured is about 30 cm. The central area of high volatile solids and metals values is less than 2 square kilometers or about 1% of Santa Monica Bay. On August 20, 1976, six grab samples and six TV lowerings were unable to locate any sludge in the "sludge area".

Los Angeles County's treatment processes initially remove 70% of the incoming suspended solids but these are partly re-added to the 350 mgd (13,300 m^3 per day) discharged so that the amount of solids entering the sea is about 330 metric tons (364 short tons) per day.

Discharge to the sea is via two major diffuser outfalls that release at depths of 50 to 60 meters off Whites Point, Palos Verdes Peninsula. The effluent plume is then subject to currents that generally flow parallel to the contours (predominantly to the north west). Some of the solids released combine with each other, with plankton, and with fine rock particles in the water to form a material that settles to the sea floor. This outfall-related sediment forms an elongated oval about 10 km long and 2 km wide; maximum depth observed is about 30 cm. Within this perimeter trace metals and chlorinated hydrocarbon levels can be contoured. All correlate closely with each other and rise to maximum values about 2 km NW of the outfall centroid at a depth of 60 meters.

3.3 THE DEEP WATER DISPOSAL ALTERNATIVE: MODELING FOR SLUDGE DISPOSAL IN THE SANTA MONICA AND SAN PEDRO BASINS

William K. Faisst*

Environmental Quality Laboratory
California Institute of Technology
Pasadena, California

This abstract summarizes research on digested sewage sludge and modeling of sludge disposal done under the joint auspices of the Department of Environmental Engineering Science and the Environmental Quality Laboratory of the California Institute of Technology (Ref. 5). This work is part of an ongoing effort in the area of residuals management that includes basic laboratory research, conceptual engineering modeling and economic analysis of important environmental problems. In the laboratory investigations, the specific characteristics of a particular problem area, such as sewage sludge treatment and disposal, are identified. Engineering modeling efforts then draw on laboratory work in order to propose feasible alternatives which can be compared on a basis of both potential environmental impacts and economic viability. The end results of all efforts should be a solid framework of facts and alternatives for use by the decision-makers who must select the actual plan.

Sewage sludge has usually been characterized only for such gross constituents as total solids, total trace metals, and pesticides. In this work, the sludge particle system was approached on a much more detailed level. There is strong evidence that the particles in digested sludge may cause serious deleterious effects when discharged near the productive surface waters of the ocean. Such effects include disruption of light penetration into the water column. This can drastically reduce photosynthesis, the primary productivity in the ocean. Sludge particles discharged to the ocean are heavier than the surrounding water and tend

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to settle. They may "blanket" the bottom, interfering with the normal life cycles of bottom-dwelling organisms. The digested sludge, only partially stabilized by treatment processes before discharge, may also drastically alter the chemistry of the sediments where it settles.

The very fine material in the sludge does not settle easily and may be carried many kilometers by the prevailing ocean currents. The trace metals and other components incorporated into the particles are also then carried great distances. Since many marine organisms such as bivalves and zooplankton are filter feeders, the presence of sludge-particulate matter of the right size in the water column may lead to uptake of sludge contaminants in the food chain.

Experimental Measurements

The actual particle size distributions for two digested sludges were measured electronically. The measured number counts were very high, approximately 10^{12} particles per liter; the majority of the particles had diameters of less than 10 micrometers. Particles of less than 10 micrometers most readily disrupt the penetration of sunlight in sea water and are selectively chosen by many filter feeders in the ocean. Such particle systems also have very high specific surface areas available for chemical reactions such as adsorption and ion exchanges. The total sludge surface area per unit volume, calculated from the particle size data, is several orders of magnitude greater than that of natural seawater.

Experiments were carried out to examine the interactions of sludge particles and trace metals during both oxic mixing and sedimentation in seawater. These experiments simulated the discharge of sludge to the ocean. The sedimentation experiments were run at different dilutions (volume of seawater to volume of sludge) to see if sedimentation characteristics changed as the particle concentration was decreased. A ten-fold dilution increase slowed the particle settling velocity distribution by an order of magnitude. This result suggests that coagulation of the sludge particles may be an important phenomenon in the ocean.

Slower sedimentation rates imply transport over much larger distances in the ocean. To a first approximation, the trace metals measured (copper, chromium, iron, nickel, lead and zinc) settled with the same mean velocity as the particles.

The mixing experiments simulated the travel of sludge particles in oxygen-rich seawater. For mixing times of up to 28 days, less than ten percent of the solids dissolved or were oxidized; nickel was the only trace metal that mobilized away from the particles. The concentration of dissolved trace metals was also measured in the digested sludge. All the metals were in the particle form at greater than 99 percent except for manganese, which was less than two percent soluble. The low solubility of the trace metals, both in the sludge and upon mixing with seawater, suggests that the metals would not be available in their more toxic soluble forms.

Modeling for Ocean Disposal

The results of the experimental work were combined with existing information to propose and model a possible sludge disposal scheme to the San Pedro and Santa Monica Basins off Southern California. These deep (greater than 800 meters) geologic structures are close to the shore (less than 20 kilometers) and nearly devoid of life. It is assumed that sludge discharged near the basin bottoms would be trapped in the sediments. A combination of hydraulic computer simulations and sedimentation calculations suggests that the initial plume would rise no more than 120 meters for releases at depths of 730 meters, and that the solids would reach the sediments within 10 km of the point of discharge. Initial dilutions were estimated to be 450 to 2600.

Mass balances on the oxidizable chemical constituents in sludge indicated that the nearly anoxic waters of the basins would become wholly anoxic as a result of proposed discharges. From chemical-equilibrium computer modeling of the sludge digester and dilutions of sludge in anoxic seawater, it was predicted that the chemistry of all trace metals except Cr and Mn will be controlled by the precipitation of metal sulfide solids.

The net environmental impacts of this scheme should be salutary. The trace metals in the sludge should be immobilized in the anaerobic bottom sediments of the basins. Apparently no life forms higher than bacteria are there to be disrupted. The proposed deep-water discharges would remove the need for potentially expensive and energy-intensive land disposal alternatives and end discharge to the highly productive water near the ocean surface.

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3.4 UPGRADING WASTEWATER TREATMENT AND MONITORING RECENT MARINE ENVIRONMENTAL TRENDS FOR THE LOS ANGELES COUNTY SANITATION DISTRICTS

Irwin Haydock, Ph. D.

Supervisor, Ocean Monitoring and Research
Monitoring Section

and

James F. Stahl

Supervising Project Engineer
Research Section
Los Angeles County Sanitation Districts
Whittier, California

The Los Angeles County Sanitation Districts (LASCD) presently operate a 400 MGD Joint Water Pollution Control Plant (JWPCP), located in Carson, California. The facility is a primary treatment, utilizing bar screens, aerated grit chambers and rectangular primary clarifiers. The raw sludge is anaerobically digested in well mixed single stage units and the digested sludge is de-watered with horizontal scroll centrifuges. The de-watered sludge undergoes open air drying and composting. Primary effluent along with centrate is pumped through a series of submarine outfalls, which terminate some two miles offshore in a multiport diffuser system along the 200 foot contour of the Palos Verdes Shelf.

Extensive and intensive monitoring of water quality of surface, sub-surface and bottom regions is carried out to assure compliance with current water quality objectives. Shoreline, nearshore, and offshore samples of many types of organisms are taken to monitor the abundance, health and diversity of the marine communities off Palos Verdes.

As the result of an extensive research and design program, (Ref. 1), a plan of upgrading the existing treatment has been initiated, in addition to implementing an industrial waste source control program. In addition to capital improvements to the existing processes, new processes have included polymer dosing to enhance primary clarification, effluent screens, treatment of digester cleanings and a two-stage centrifugation system for the recovery of digested sludge solids. Discounting the effects of industrial waste source control, these processes will result in the following effluent quality improvements by 1977: double the net removal of suspended solids from the present 40% to 80%, increase the net removal of BODs from about 30% at present to 55%, increase heavy metals recoveries by factors of two to five, eliminate the discharge of floatable wastes to the ocean, and eliminate the discharge of digested sludge to the ocean.

The effluent quality and economic and energy expenditures associated with the upgraded system are compared with that achievable by secondary treatment. The increased expenditures associated with secondary treatment do not appear justifiable in light of the evidence of the Districts' investigations, (Refs. 2 and 3), as well as others, (Ref. 4).

A recent environmental study report, Ref. 3, has fully discussed the planning of future treatment alternatives designed to meet new water quality standards promulgated under PL 92-500. In addition, this report has assessed the observed marine impacts of the present primary wastewater discharge and attempted to predict the future results of upgrading the system to advanced treatment and, eventually, to full secondary treatment.

An analysis of the results obtained from extensive benthic invertebrate monitoring at a series of deep water stations has provided some clear examples of the impact of the present primary wastewater discharge, especially the effect of the solids in the effluent. In addition, repeated benthic sampling since 1970 has shown trends toward an improved benthic habitat brought about principally by improvements in primary treatment alone. These system changes include: 1) optimization of outfall operation; 2) the addition of 14 new sedimentation tanks and two digesters and 3) source control of DDT, refinery thiosulfate and BODs.

The benthic response has been measured in several ways: 1) a decline in organic nitrogen in sediments of the Palos Verdes Shelf; 2) sharply reduced concentrations and areal extent of sulfide-bearing areas and particulates of wastewater origin; 3) a corresponding increase in benthic diversity and biomass, along with a substantial decrease in frequency and distribution of some indicator species especially dominant in the immediate outfall vicinity. It is important to note that the observed changes have occurred prior to the implementation of the advanced treatment system that will remove substantially more solids in the near future.

A very tentative prediction of the future benthic response to advanced waste treatment may be indicated by comparison of excess or enriched biomass in outfall areas as compared to control locations along the Southern California coastal shelf. The Southern California Coastal Water Research Project (SCCWRP) has made such an attempt, (Ref. 5), taking into account a presumed relationship between the total suspended solids (nutrients) discharged at various coastal outfalls and the areal amount of standing crop biomass enhancement observed in the vicinity of each outfall. When plotted together, there results an intriguing direct, apprently linear, log-log relationship between enhanced standing crop biomass and total discharged solids per year. These calculations imply that a substantial decrease in benthic biomass will result from advanced treatment removal of suspended solids. Coincident with this decreased biomass, it is also possible to predict that diversity will increase since there is generally an inverse relationship between diversity and solids emissions, presumably through enhancement of a few particle-feeding dominant species.

3.4 (cont.)

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3.5 SEDIMENTATION MODELING FOR SLUDGE IN SEA WATER

Robert C. Y. Koh

Environmental Quality Laboratory
California Institute of Technology
Pasadena, California

A simulation model developed by Koh (Ref. 1) is used to examine the deposition of particulates in sludge when discharged into the ocean environment. When typical sewage sludge is discharged through a pipeline at the bottom of the ocean, it would rise due to the fact that its density is usually less than that of seawater. Faisst (Ref. 2) presented results of plume rise calculations for postulated pipeline disposal of sludge in the Southern California deep basins, which indicate a range of rise to 30 to over 100 meters. After the phase of buoyant rise, the entrained sludge particles would drift with the ocean currents while settling towards the bottom. Typical sludge particle settling velocities encompass a range of 10^{-4} cm/sec to 10^{-2} cm/sec. Typical current velocities in the deep ocean tend to be rather small, perhaps on the order of a few centimeters per second.

It is assumed that the ocean bathymetry is as shown in Figure 3.5.1 with bottom contours parallel to shore. A rectangular grid 50 x 30 km is used in the simulation where the sludge is assumed to be initially at a height z above the bottom. The ocean current is assumed to be given by a Markov process with zero mean:

$$u_i = 0.9\, u_{i-1} + u_i'$$

$$v_i = 0.76\, v_{i-1} + v_i'$$

where (u_i, v_i) are the alongshore and onshore-offshore current speeds and (u_i', v_i') are random uncorrelated Gaussian variates with mean zero and standard deviations 1.5 and 1 cm/sec respectively. Several different discharge locations (A,B,C, and D in Figure 3.5.1 corresponding to water depths of 100, 220, 400, 640 meters), fall velocities (10^{-2},10^{-3},10^{-4},cm/sec)

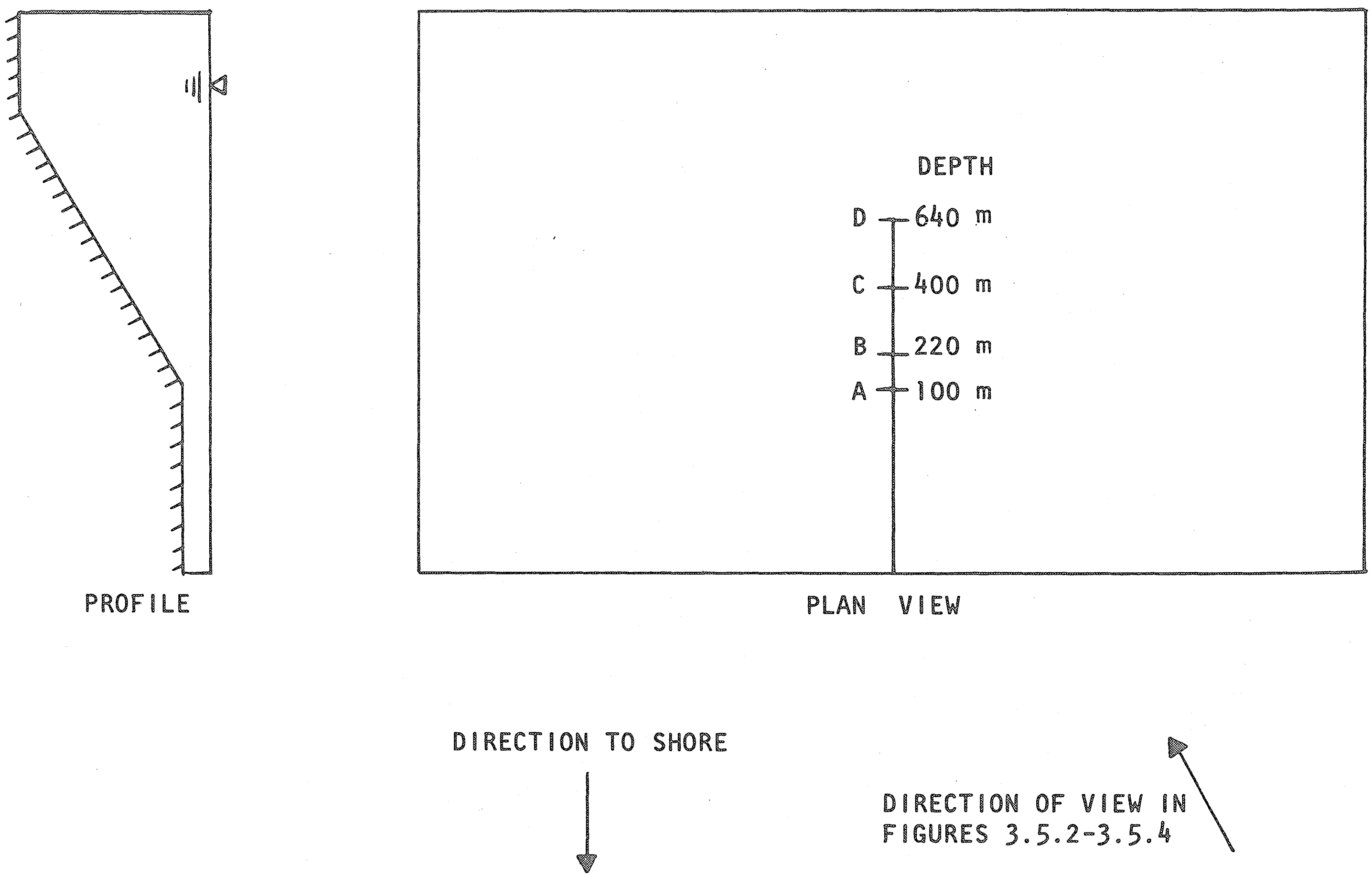

Figure 3.5.1 Physical Layout of Sludge Fallout Field Model

and heights z (20, 40, and 70 meters) are used in the simulation. In all calculations, the height z is given a dispersion of ± 5 meters and the fall velocity, w_s a dispersion of ± 0.1 w_s (both uniformly distributed).

The results are summarized in Table 3.5.1 and example distributions of fallout patterns are shown in Figures 3.5.2 to 3.5.4. It can be seen that the width of the area of deposition is relatively small being on the order of a few kilometers. A significant portion of the discharged material remains in the grid, the amount being larger for the materials with large fall velocities. The settling rate is on the order of 0.02 to 0.1 per square kilometer, i.e. if the discharge is 100 tons/day, then the settling rate would be on the order of 2 to 10 tons/day - km^2 in the vicinity of the discharge.

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Table 3.5.1

Summary of Results

Depth at Discharge Point (m)	Initial Height of Particles above Bottom (m)	Fall Velocity (cm/sec)	% of Particles Remaining in grid	Peak Fallout Rate (km^{-2})
100	20	10^{-2}	99	0.1
100	20	10^{-3}	65	0.025
100	20	10^{-4}	35	0.015
220	20	10^{-3}	85	0.050
220	40	10^{-3}	75	0.035
220	70	10^{-3}	60	0.020
400	40	10^{-3}	75	0.035
640	40	10^{-3}	70	0.015

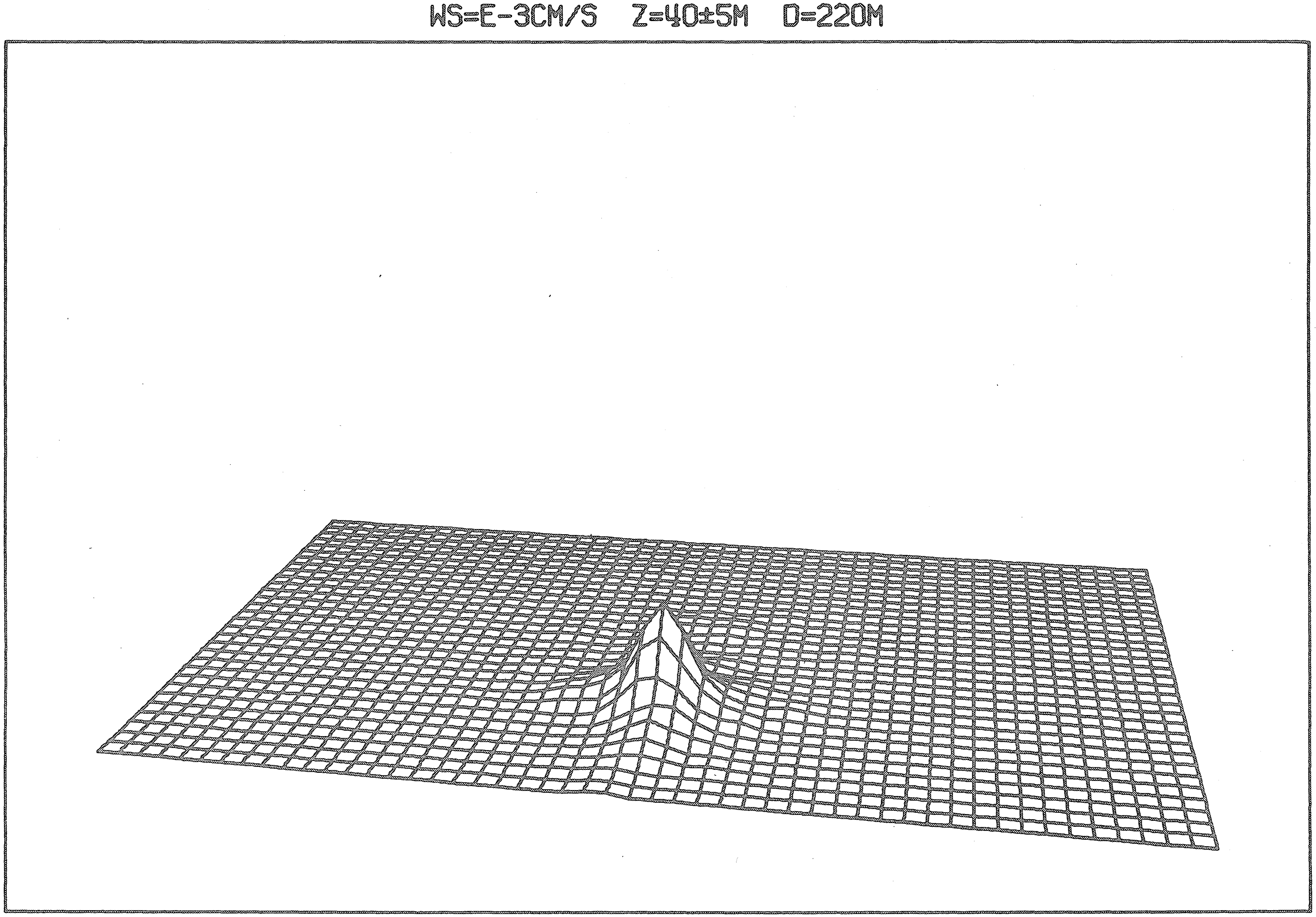

Figure 3.5.2 Bottom fallout rate distribution. Fall velocity of sludge particles = 10^{-3} cm/sec $\pm 10^{-4}$ cm/sec, initial height = 40 $\pm$ 5 meters, depth of water at discharge point = 220 m.

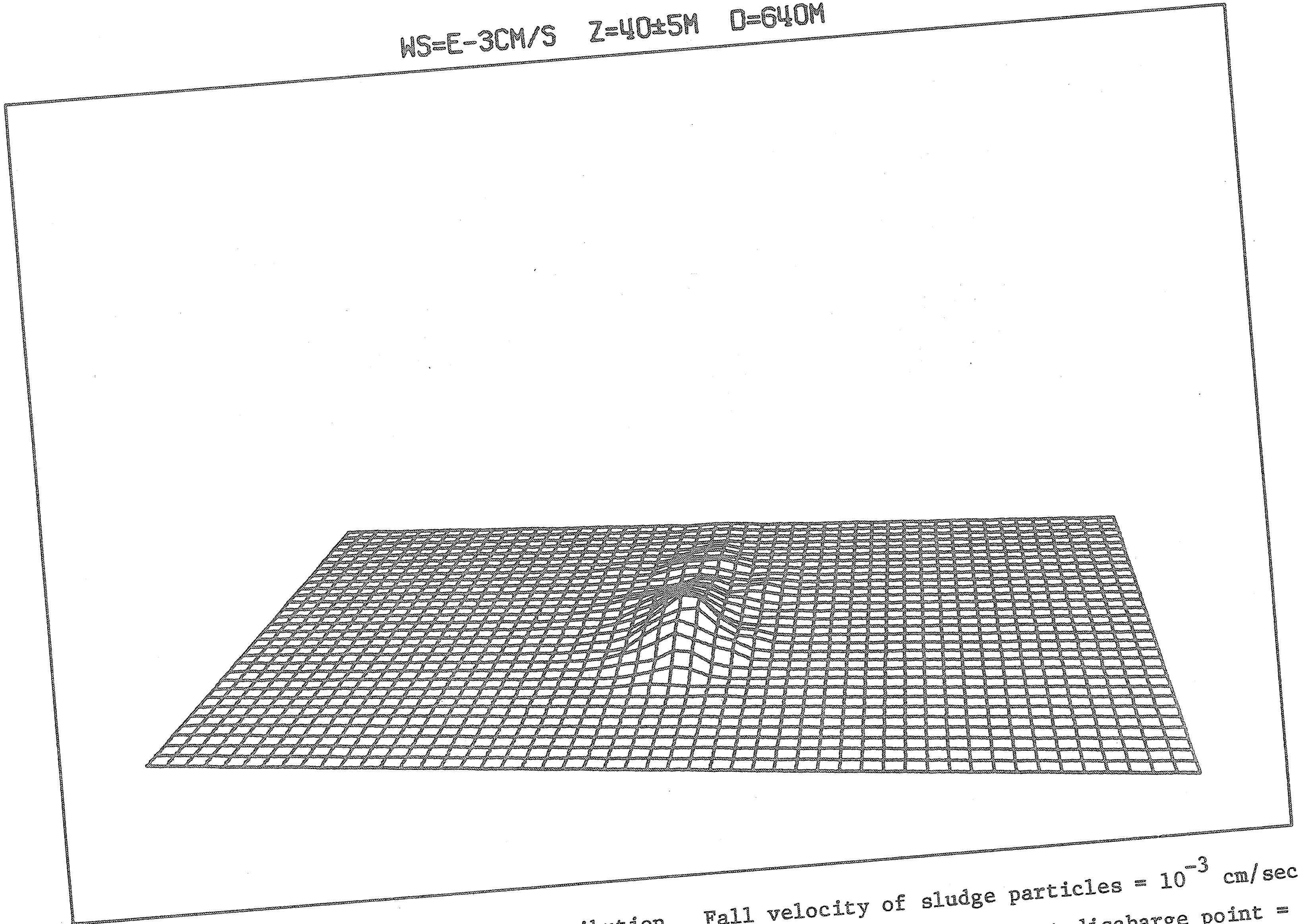

Figure 3.5.3 Bottom fallout rate distribution. Fall velocity of sludge particles = 10^{-3} cm/sec $\pm 10^{-4}$ cm/sec, initial height = 40 $\pm$ 5 meters, depth of water at discharge point = 640 m.

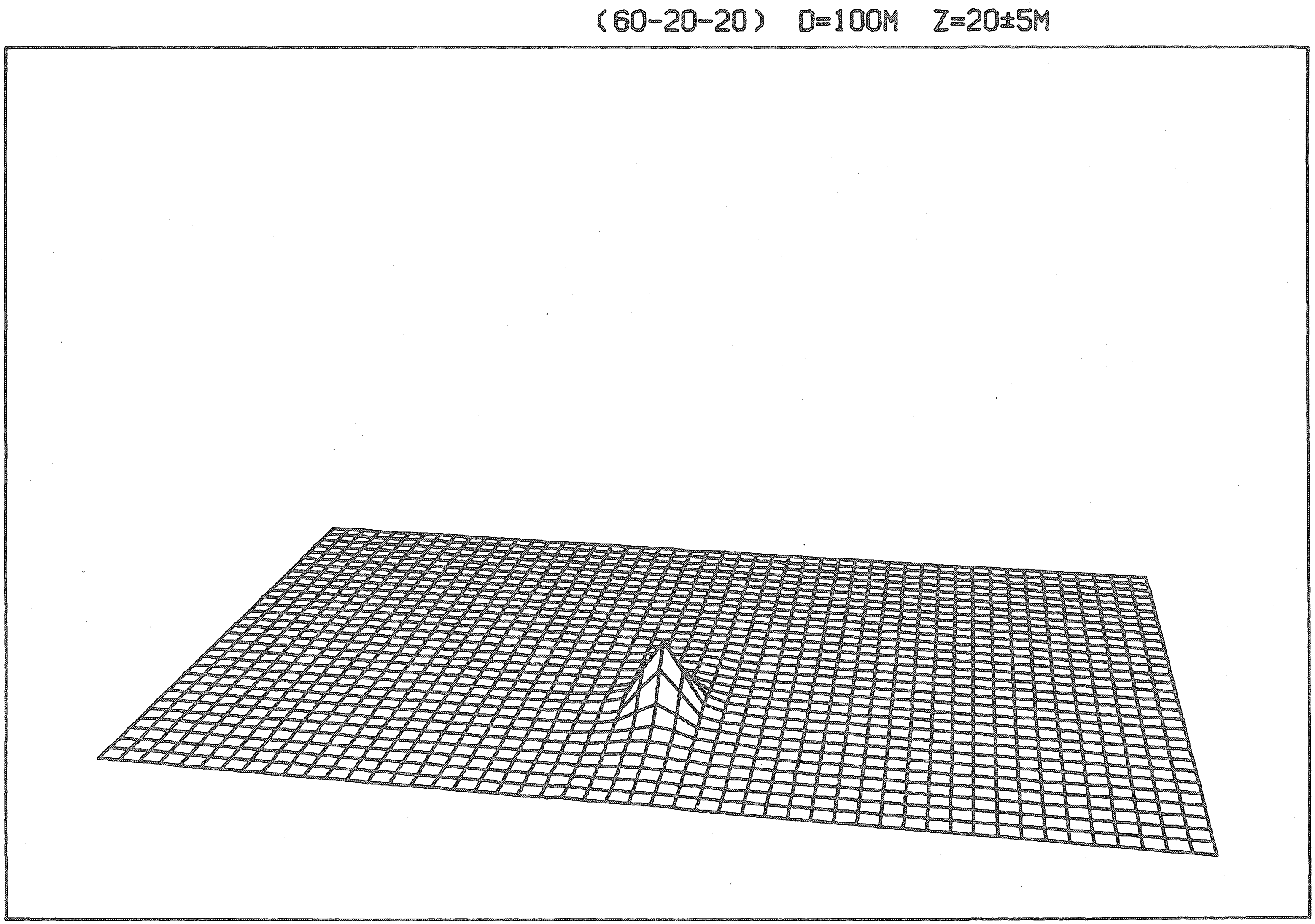

Figure 3.5.4 Bottom fallout rate distribution. Fall velocity of sludge particles = 60%:10^{-2} cm/sec, 20%:10^{-3} cm/sec, 20%:10^{-4} cm/sec, initial height = 20 $\pm$ 5, depth of water at discharge point = 100 m.

3.6 SPECIAL EFFECTS OF WASTEWATER SOLIDS ON MARINE LIFE

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Consitituents discharged off Palos Verdes via the JWPCP outfalls have special effects generally not found or not caused by other local discharges. One of these is a fin erosion disease that affects at least 40 species of bottom fish, but primarily the Dover sole (*Microstomus pacificus*). The disease is persistent (unresponsive to recent treatment changes) yet not infectious. It is associated with increased tissue levels of chlorinated hydrocarbons which the fish accumulate directly from contaminated sediments or contaminated benthic food organisms. Fish with eroded fins from other localities may be migrants from Palos Verdes. It also may be relevant to this conference that the Dover sole is one of several species known to undertake spawning migration into deep water (to 1,200 meters).

Recently we examined benthic biological data from a number of large and small discharge sites. A broad overview of these data suggests there is a trend of increased biomass and decreased diversity with increased mass emission rates of solids.

3.7 ENVIRONMENTAL EFFECTS OF HYPERION TREATMENT PLANT SLUDGE AND LIQUID EFFLUENT IN SANTA MONICA BAY

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The authors have assembled a considerable amount of site-specific material, much of it previously unpublished, from physical and biological studies near the Hyperion Treatment Plant outfalls. With the extensive co-operation of the Southern California Coastal Water Research Project (SCCWRP) and the Hyperion Treatment Plant Laboratories, existing raw data was obtained from the files of these agencies on concentrations of sludge-derived substances in the sediments around the 7-mile sludge outfall; on distributions of organisms in the vicinity of both the 7-mile and 5-mile outfalls; and on the distribution of coliform bacteria and chlorinated hydrocarbons in the water columns. This report graphically presents and summarizes these data, identifies deficiencies in existing sampling programs, reviews the data in light of the literature and draws tentative conclusions about the fate of sludge and wastewater derived toxic and nutrient substances, and about their potential economic effects on the fishery.

REFERENCE

1. The above abstract refers to the Marine Physical and Biological sections of the draft Environmental Impact Statement on the City of Los Angeles Wastewater Facilities Plan. The draft EIS has not yet been published.

3.8 THE FATE OF ENTEROVIRUSES IN SEWAGE AND SLUDGE DISCHARGED INTO THE MARINE ENVIRONMENT

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The fate of viruses and pathogens discharged into the ocean in sewage effluents is not known for certain. They are likely inactivated in the same manner that coliform bacteria are--through sedimentation, predation by marine bacteria and filter feeders, damage by ultraviolet light, abrupt changes from reducing to oxidizing environment or because of some antiviral agent present in the sea. We have been able to detect enteroviruses and coliform bacteria in the marine environment in the vicinity of outfalls. The estimated time required for 90 percent of viruses discharged into seawater to become inactivated was estimated to be three to six times as long as that for total coliform bacteria. Marine sediment-sludge samples from the vicinity of outfalls were examined for the presence of enteroviruses and total coliform bacteria. Only one of eight samples tested was positive for virus. The coliform levels ranged from less than 200 to 1.6×10^6 most probable number/kg of sample. Viruses adsorb to particulate material in sewage and sludge, giving them protection from inactivation and causing a problem in isolating them for quantitation.

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3.9 CHARACTERIZATION OF DOMESTIC AND INDUSTRIAL SEWAGE IN SOUTHERN CALIFORNIA COASTAL SEDIMENTS USING NITROGEN, CARBON, SULFUR AND URANIUM TRACERS

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The nitrogen isotope ratio ($^{15}N/^{14}N$) is shown to be an effective tracer of sewage discharge on the San Pedro Shelf. Isotopic fractionation of $^{15}N/^{14}N$ during release of amino compounds or ammonia (as a consequence of bacterial degradation of organic detritus) appears to be negligible. Nitrogen isotope ratios, therefore, may be considered a conservative component for tracing the source of organic matter deposited in marine sediment.

A "degradation-mixing" model has been developed to aid in the interpretation of geochemical processes occurring in sewage-contaminated marine sediment near San Pedro, Southern California. Cadmium and sulfur are shown not to be mobilized during sewage deposition and degradation. Uranium and nitrogen are shown to be incorporated in the "organic" fraction of sewage effluent and are released during bacterial degradation of the organic matter. Uranium is not enriched from seawater in highly reducing sewage-contaminated sediments. The high content of uranium in the effluent particulates, 18 ppm, also allows it to be used for tracing the deposition of sewage particles in marine sediment. The stable isotope ratio of sulfur ($^{34}S/^{32}S$) is used to demonstrate that sulfur enrichment occurs in the sediment by *in situ* reduction of sea water sulfate, in addition to that provided in sewage.

The data summarized by Morel *et al*. (Reference 5) are used to show that Zn, Ag, Cr, Cu and Co appear to be incorporated in the "organic" fraction of the sewage effluent, whereas Pb is not.

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3.10 DISPERSION AND BIOLOGICAL UPTAKE OF PARTICULATE-ASSOCIATED TRACE CONTAMINANTS OFF THE PALOS VERDES OUTFALLS

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Many trace contaminants such as toxic metals and synthetic organics are associated with particulates in municipal wastewaters. Submarine discharge of JWPCP effluent via the Palos Verdes outfalls has resulted in highly-contaminated suspended particulates and bottom sediments in this discharge zone. These contaminated solids appear to act as pollutant sources to local organisms. For example, although DDT and PCB inputs via the outfalls dropped by an order-of-magnitude between 1972 and 1975, both bottom sediment and flatfish muscle tissue (median) concentrations decreased by only a factor of about 1.5 over this period. Further, flatfish exposed for one year in the SCCWRP laboratory to clean seawater, clean food and contaminated Palos Verdes sediments increased their tissue burdens of DDT and PCB by two orders-of-magnitude. In contrast, flatfish trawled from the highly-contaminated sediments showed little or no uptake of metals. However, rock scallops exposed to the suspended outfall particulates exhibited at least 2-fold enhancements of six metals in muscle and/or gonad tissues.

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CHAPTER 4

SUMMARIES OF AFTERNOON DISCUSSION SESSIONS

This section contains summaries of the three afternoon discussion sessions. It attempts to summarize the most important ideas mentioned by the speakers as well as questions and comments from the floor. The first session considered general aspects of sludge disposal in the ocean; the second session dealt with the availability of reliable oceanographic data relevant to sludge disposal effects; and the third session centered on physical, chemical and biological effects of sludge in the ocean.

4.1 SESSION I: OCEAN SLUDGE DISPOSAL ALTERNATIVES

Moderator: Norman H. Brooks, Director, Environmental Quality Laboratory, California Institute of Technology

Norman Brooks began the session by presenting a box model for evaluating the overall impact of ocean sludge disposal (Fig. 4.1.1, p.42) and by stating his belief that a reasonably satisfactory assessment of the impact is possible. He commented on various sludge pre-treatment schemes prior to ocean disposal, such as pre-mixing the sludge with sea water to adjust plume depth; and reviewed various strategies for sludge residual disposal in the ocean, including dispersal, containment, and limited dispersal within a deep ocean basin. Brooks described two basic types of delivery systems with sub-categories as follows:

A. Pipeline

(1) Mix sludge with effluent for discharge through an effluent outfall

(2) Discharge through separate sludge outfalls

(a) such as existing Los Angeles City's Hyperion sludge outfall (7 miles, 320 feet deep)

(b) existing sludge outfall extended

(c) new outfalls, with depths up to 2400 feet

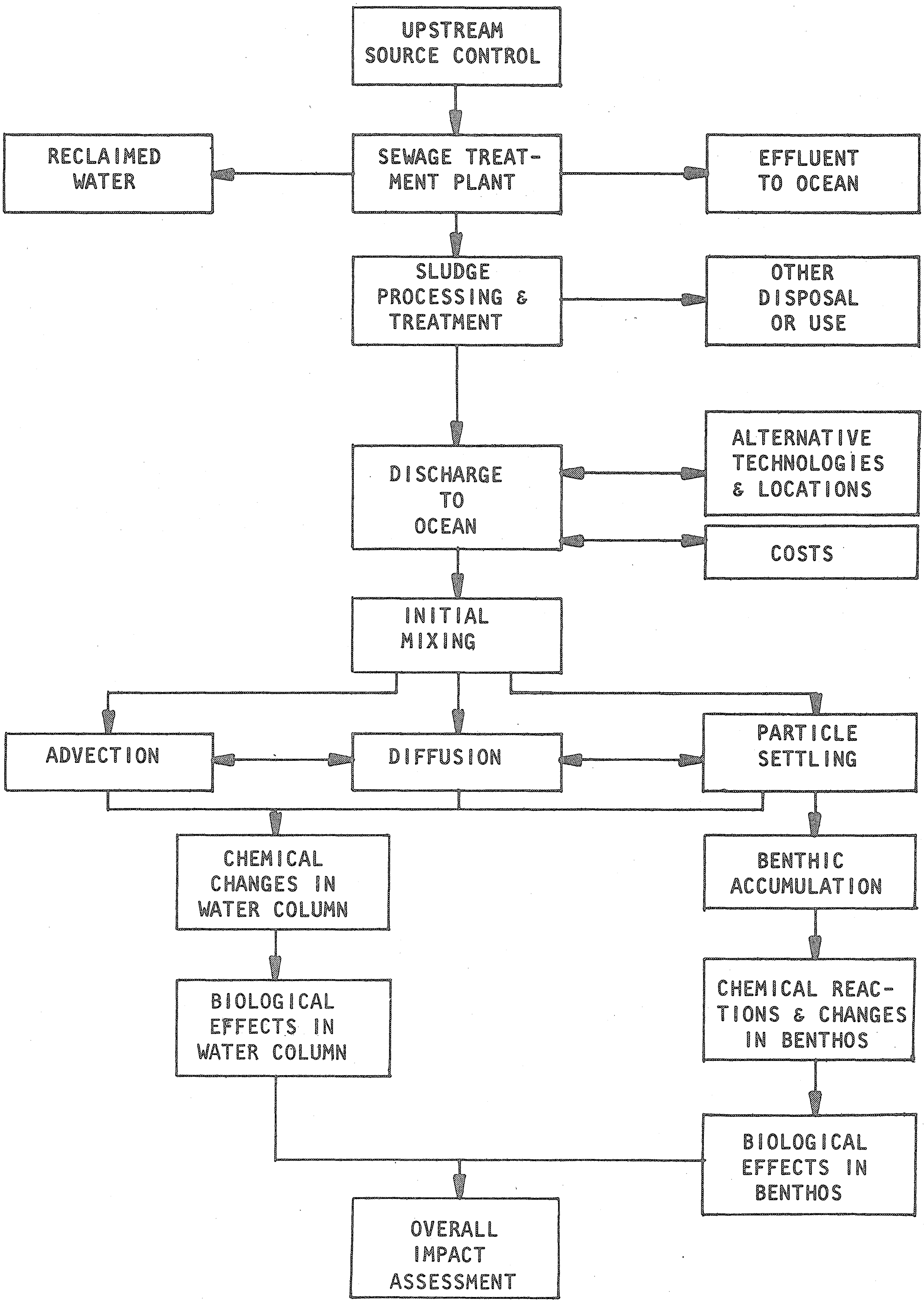

Figure 4.1.1 Box model for evaluating the overall impact of ocean sludge disposal.

B. Barge transport to deep water sites

(1) bottom dump
(2) pumped discharge
(3) snorkel pipe to depth
(4) containerized

Bill Davis briefly described the Regional Wastewater Solids Management Program for the Los Angeles/Orange County Metropolitan Area (LA/OMA Project). Project funding is 75 percent federal, with state and local agencies contributing 12.5 percent each. Their Phase I report outlining 17 treatment systems involved in the disposal of digested primary and waste activated sludge will be available soon.* The next phase of the study involves detailed research on each system. The study has assumed implementation of secondary treatment throughout the basin with an emphasis on re-utilization of sludges where feasible. Due to state and federal views, their funds cannot be used to study ocean disposal alternatives. The deep ocean disposal schemes will be considered, however, with $75,000 to be requested from the local sewage agencies. Studies under way include addition of sludge to agricultural land, pyrolysis and land disposal. The expected termination date of the study is December 1978.

A question from the floor was raised on what are the alternatives to ocean disposal for sludge. The reply was incineration, pyrolysis, land fill and agricultural use.

Another questioner asked what happens to the trace metals in the sludge when it is used in agriculture. The answer was that there is currently much research in this area but little information, as yet, on the effects of trace metals on plants and their transmission through the food chain.

Another question dealt with the use of sludge for fuel. Tim Haug of LA/OMA responded that LA/OMA is one of the many groups presently looking into this alternative. Pyrolysis is useful because the resulting gases are of high energy content and can be cleaned before burning. The fate

*Subsequently issued, and available as follows: LA/OMA Project Phase I Report, August 1976 (LA/OMA, P.O. Box 4998, Whittier, CA 90607).

of trace metals in pyrolysis is not yet certain. Brooks reminded the audience that digested sludge is only about 2-3% solids as it comes from the digesters and it takes energy to further concentrate the solid fraction.

Brooks closed the session by asking what reaction the audience had to deep ocean basin discharge. David Young of the Southern California Coastal Water Research Project (SCCWRP) said more information was needed on the deep basins, especially the oxidation-reduction characteristics of the bottom sediments and the long-term impact of sludge disposal. Irwin Haydock of the Los Angeles County Sanitation Districts (LACSD) mentioned some thoughts he had on regional sludge management based on sedimentary cells and the possibility of using naturally-occurring turbidity currents in submarine canyons to transport sludge solids to the deep basins.

4.2 SESSION II: DATA AVAILABILITY AND NEEDS

Moderator: Willard Bascom - Director, Southern California Coastal Water Research Project

William Faisst opened the session by reviewing the data compiled by Hillson for the EQL data bank on the Southern California Bight, especially the Santa Monica Basin. Density, salinity, temperature, biomass and dissolved oxygen data were collected. Information on currents was hard to find, especially at depth; and information on sedimentation rates and the stability of the water masses with respect to turnover was not available. Some geographic areas appeared to be well documented while others were not covered at all. There was also a question on whether measured temperatures and salinity data were true *in situ* values.

A question was raised about water column biomass above the near-coast basins. Responses were that most measurements were taken only near the surface and that, although the Bureau of Land Management has been doing sampling, their stations are too far from the coast, too spread out and too infrequently sampled.

David Young asked if the biomass data that have been collected could be extrapolated to the nearshore basins. The responses were that care must be taken in making extrapolations because there are long-term cycles which appear to be associated with local climate, as shown by Fourier analysis of core samples, done at UCLA, and because the basins appear to be stable (little turnover).

Willard Bascom started his discussion of data needs by saying it was not logical to have ocean discharge of sludge outlawed without due consideration. Laws should be written so that they can be applied flexibly in place and time to give the best solution for the circumstances and not specify one uniform solution. He felt that very little was known about currents in the Southern California Bight, including seasonal fluctuations. He said little data is available on basins, including thickness and redox levels of sediments. Since only 10 percent of the discharged wastewater solids could be accounted for in sediments, where do the rest go? What are the life cycles of local marine organisms including migration and advection? Are there population exchanges with the open ocean? Do plankton occupy different levels at different times? Since the Black Sea has had a reducing environment below 100 m with no surface problems, it would be a good place to study anoxic basins. He also felt the various data collection programs are neither uniformly done nor of uniform accuracy. The influence of extreme events and long-term cycles should also be examined.

Bill Davis of LA/OMA said Bascom had a different opinion of data availability than Norman Brooks. Brooks responded that his assessment of predictive capability depends on having adequate data of the type Bascom described.

A question was raised about the uniformity of data collection efforts of various agencies, and Bascom responded that this is especially a problem in biota-sampling and taxonomy. He said a local attempt is being made to standardize taxonomy. Irwin Haydock of LACSD mentioned the need for coefficients to compare the results of different biota sampling techniques. He also saw a need for a comprehensive approach to data collection and analysis and mentioned the computerized data management system being developed at LACSD.

Dorothy Soule of USC said better co-ordination among agencies was needed for more efficient data collection -- such as using one agency's facilities to collect data needed by other agencies.

James Morgan of Caltech said the data base on wastewater, even at the treatment plant before discharge, is poor and does not usually contain information on all potentially dangerous substances. He gave arsenic as an example for which there is a lack of data on both abundance and toxicity. Bascom responded that people are beginning to recognize this and that SCCWRP was starting to look into it. Right now, there is no uniformity in plant monitoring within the Los Angeles region.

Finally, Larry Klapow of the State Water Resources Control Board (Sacramento) asked why the conference was not considering the other disposal alternative so as to guide policy makers. Morgan responded that in Southern California much more is known about ocean disposal than land disposal so that this conference makes sense here. Brooks added that since state and federal regulations have prevented consideration of ocean sludge disposal, it was up to an organization such as EQL to host a conference to discuss the possibility. Probably as the LA/OMA study progresses there will be chances to discuss the full range of alternatives.

4.3 SESSION III: ENVIRONMENTAL AND ECOLOGICAL CONSEQUENCES OF OCEAN SLUDGE DISPOSAL

Moderator: James J. Morgan - Executive Officer,
Environmental Engineering Science,
California Institute of Technology

James Morgan opened the session by presenting a framework for discussing effects divided into two areas: short-term environmental effects of a physical, chemical or biological nature, such as sedimentation rates or survival of pathogens; and long-term ecological effects, such as changes in total community structure.

Emil Kalil of UCLA discussed the use of nitrogen isotopic ratios as an effective tracer of sewage solids in coastal sediments. Nitrogen isotopic ratios have certain advantages over carbon as was used by Myers (see Section 3.9, p. 33). Morgan commented that this is a promising technique to trace the missing 90% of the sludge noted by Bascom (see Section 4.2, p. 45).

Rodney Morris of the California State University at Long Beach described work he had done on the fate of viruses and pathogens in coastal waters. Generally little is known on viral removal mechanisms, and coliform organisms are not good indicators of viruses since coliform die-off is much faster. Viruses are not being monitored in the coastal waters nor in coastal filter feeders on a regular basis. The only data that have been taken were for research projects (see Section 3.8, p. 31).

Morgan expressed his concern about the discharge of three types of foreign substances which should be isolated from the environment: pathogens and viruses, synthetic organic compounds, and toxic metals. It was suggested from the audience that petroleum hydrocarbons should be added to this list.

Alan Mearns of SCCWRP commented on the limiting factor approach to wastewater discharge, i.e., productivity cannot be increased in already highly productive areas by addition of nutrients. This could be applied to sewage disposal by picking disposal sites that already contain benthic communities similar to those produced by sewage disposal. He also mentioned the case of bottom recovery at the old Orange County outfall when sewage discharge was halted there, and asked if other sites would also recover. Specifically, is it better to use deep basins which might not recover easily because of their low temperatures or shallower sites that might recover more easily?

A question was raised about the use of gamma radiation to destroy viruses, and William Faisst answered by mentioning current research in the radiological biocide area at MIT and Sandia Labs.

Robert Davies of HDR Ecosciences commented on the recently collected Santa Monica Bay data used in the draft EIS of the Los Angeles City wastewater Facilities Plan (see Section 3.7, p. 30).

Morgan closed the session by stating his philosophy toward ocean discharge. He said waste nutrients and metals already naturally present in the ocean could be dispersed if the effluent-induced levels were not drastically above natural levels. In terms of unnatural materials like synthetic organics and toxic metals, wastes should be contained, not dispersed. Bio-accumulation of unnatural materials should definitely be avoided. Because of this, effective source control would make ocean disposal of sludge much more acceptable. If it can be shown that sludge materials will be effectively contained within the deep, nearshore ocean basins, then such disposal would be acceptable to him. When asked how much DDT could be dumped into the ocean, Morgan responded that none should be dumped until reliable toxicological data were available. There was a general feeling that toxicological data were needed on numerous compounds and under conditions similar to the marine environment, such as existing sediment content levels and body burden levels.

Norman Brooks concluded the conference with the thought that deep basin disposal of sewage sludge can be viewed as possible containment of wastes in the sediment.

CHAPTER 5
LIST OF CONFERENCE ATTENDEES

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